Indoor Deployment Strategies White Paper

NOKIA

Contents

1. Executive Summary

The growing demand for affordable mobile broadband connectivity is driving the development of Heterogeneous Networks (HetNets). A range of different cellular Radio Access Technologies (RATs) and Wi-Fi will all co-exist, and macro cells will be complemented by a multitude of smaller cells, such as micro and pico cells and Distributed Antenna Systems (DAS). The deployment strategies for HetNets are described in [NOKIA Deployment whitepaper]. The evolution of macro base stations and outdoor small cells will ensure mobile broadband coverage and capacity for the next few years. However, as around 80% of all mobile broadband traffic is consumed by users located indoors [Source: Informa], the challenge is to deliver fast and seamless connectivity to indoor users. There are multiple deployment options for providing indoor mobile broadband:

- The first step is to maximize indoor mobile broadband coverage via the existing macro base stations, for example, using lower frequency bands such as UMTS900 and LTE700/800.
- In addition, outdoor small cells can be deployed to increase outdoor macro capacity and coverage and can also help provide indoor mobile broadband in areas with high traffic load and a sufficient subscriber base (city center shopping streets, etc…).
- In addition and in important locations (enterprise customers, strategic indoor locations) operators will have to deploy indoor dedicated base stations to provide coverage and to boost capacity. This will create smaller cells in congested network areas, such as apartment complexes, tube and train stations, shopping malls, stadiums, exhibition centers and airports.
- Indoor small cells provide the lowest TCO for providing coverage and capacity in indoor hot spots in enterprises and public buildings.

This white paper outlines key deployment strategies to provide the best mobile broadband indoor user experience and explains how Nokia can help operators to address them. It discusses how to design roadmaps to expand the outdoor macro and micro layer and how to use indoor deployment to handle the increasing traffic.

2. Business and market drivers for indoor solutions

The technology drivers are described throughout this paper, together with the best network deployment options to utilize spectrum. Services are another key driver for indoor solutions as operators strive to provide users with the same or better QoS that they can get outdoors. Finally, mobile broadband traffic continues to grow significantly with the latest forecast showing ~61% compound annual growth rate (CAGR) [CISCO 2014 Reference]. The main drivers for the increase in mobile broadband come from smartphones, tablets and laptops, accounting for more than 80% of the network data.

Previously, the existing macro network was typically designed for mobility and outdoor coverage for voice services. Today, increased indoor coverage and broadband capacity is becoming more important as more traffic is consumed indoors. The main limitations of the existing macro network are:

- Limited indoor coverage – due to building penetration loss (especially from modern buildings)
- Inefficient use of spectrum resources particularly in urban and dense urban deployments
- Capacity limited
- Relatively high cost for new deployments and upgrades

Many of these limitations can be overcome with various deployment options based on indoor coverage and capacity. These options are described in this white paper. Finally, the paper provides answers on how indoor solutions can be used to prepare networks for one Gigabyte per mobile user per day by 2020.

3. Technology options for operators

Today's operators have many deployment options to enhance coverage and capacity for indoor users. Macro cell enhancements, outdoor small cells and dedicated indoor deployment are all options that can be used to further enhance the indoor user experience. Figure 1 shows the general deployment options for operators to evolve their networks. These general deployment options have been described in the Nokia white paper 'Deployment Strategies for Heterogeneous Networks'.

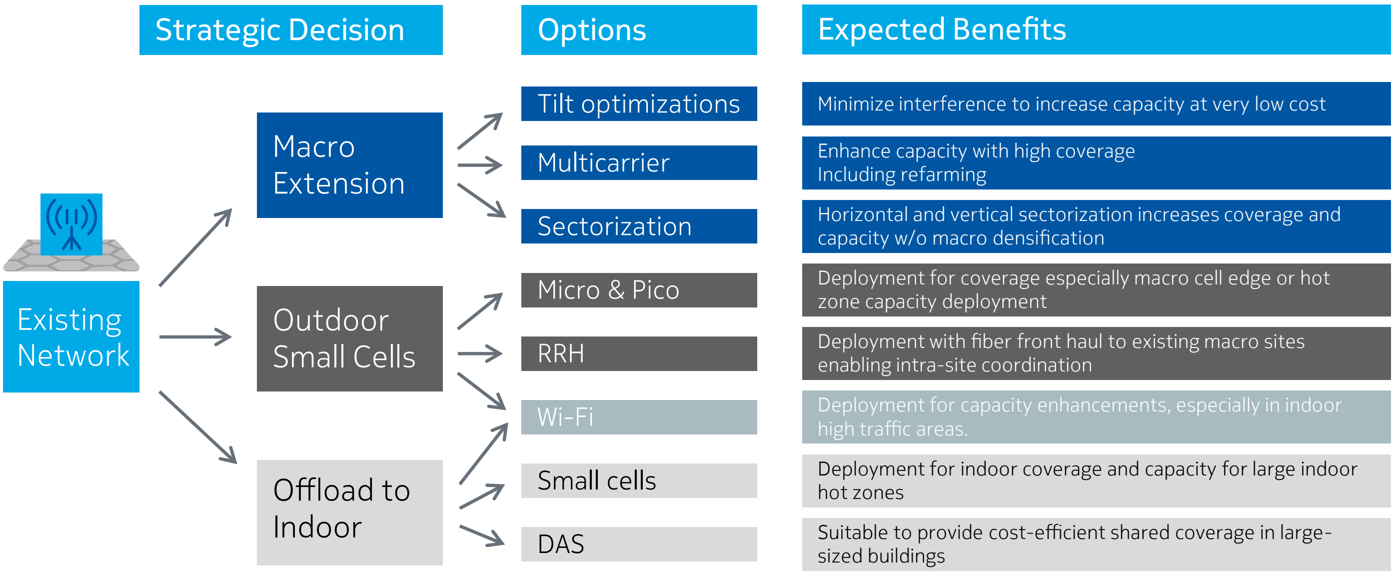


Figure 1: Strategic deployment options for outdoor macro, micro, and indoor solutions

3.1. Outdoor deployment for indoor coverage

Traditionally, cellular networks have been deployed outdoors for continuous coverage. Indoor coverage and user experience varies depending on a number of parameters, such as distance from the cell tower, the outdoor-to-indoor penetration and the services requested. However, there are many options for operators to provide better indoor coverage and capacity.

One of the most efficient methods for operators to provide coverage is to use their spectrum asset smartly. The coverage layer should be deployed at the lowest frequency available, while the capacity should be provided using higher frequencies.

Another simple way to increase the antenna gain at the base station is to split the current cells into smaller and narrowband cells by sectorization. Higher order sectorization can be deployed in both the horizontal plane by increasing the number of antennas/sectors and/or in the vertical plane by introducing Active Antenna Systems (AAS).

Deploying outdoor small cells for dense urban areas can provide indoor coverage and capacity. However, for high rise environments, outdoor small cells do not solve the challenge of indoor coverage. These environments will require either an in-building solution or a macro / micro based solution, with directional antennas pointing upwards to provide coverage and capacity.

This white paper focuses on the key deployment options to improve indoor coverage and capacity to achieve the best mobile broadband experience. The indoor deployment options will be discussed throughout this paper.

4. Indoor deployment

To overcome the path loss from walls, windows and other obstacles, indoor deployment provides an efficient way to provide indoor coverage and capacity. This section outlines some of the many options that can provide both coverage and capacity enhancement for indoor deployment.

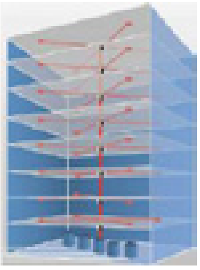
4.1. Distributed Antenna System

A DAS is the distribution of cellular RF to a network of antennas within a building to provide cellular coverage. The DAS distributes RF from a centralized radio source throughout the building using a network of RF cabling, splitters, couplers and antennas, fiber optic cabling and RF repeaters.

The aim is to create an indoor coverage layer seamlessly integrated with the macro layer and handling all voice and data traffic internal to the building, offering better quality and user experience. This indoor layer will form an underlay to the macro layer, offloading the much needed capacity from the macro layer and creating potential revenue for the operator. The benefit of DAS comes from its ability to support multiple operators (neutrality) using the same system and to be technology agnostic. Upfront costs for DAS are typically high but are offset somewhat by the ability to split the cost amongst operators, making it more suited for large and very large buildings where the high expense can be amortized across a large number of users. However, DAS has quite a rigid architecture, making growing the capacity complex and costly.

DAS solutions can be classified as passive, active, or hybrid systems.

- Passive DAS: In passive systems, the wireless signal from the RF source is distributed to the antennas for transmission, without any amplification, through a series of passive components.
- Active DAS: In active DAS, the RF signal from a source is converted to a digital signal for transmission over fiber optics or cable.
- Hybrid DAS: A hybrid DAS system is a combination of passive and active systems. In a hybrid DAS system, fiber optic or CAT5 cable is still used to connect the head end (master unit) to the remote units. However, passive DAS is used for distributing the RF to the antennas from the remote units.



Indoor DAS

Outdoor DAS

Figure 2: Distributed Antenna Systems (DAS)

4.2. Indoor small cells

It was shown in the previous section that indoor small cells are needed to meet the capacity requirements for dense indoor locations due to the high outdoor-to-indoor penetration. DAS supports good indoor coverage but is unable to provide the needed capacity. In this section we will describe several options to deploy indoor small cells for different indoor environments.

4.2.1. Indoor coverage and capacity complemented by small cells

The potential for indoor offload is quite significant, since a large percentage of global wireless data traffic is generated indoors and most if not all smartphones and laptops are equipped with Wi-Fi connectivity. The indoor offload will connect users to the nearest connectivity node, reducing interference and transmission power, increasing capacity and reducing battery consumption.

Load-based traffic steering between the macro, micro, pico clusters and Wi-Fi layers will be needed in order to use the available spectrum efficiently. Furthermore, automatic authentication is needed for Wi-Fi offload to reach its full potential, because manual authentication will prevent some users from going through the registration process.

Figure 3 shows an example of indoor data offloading to Wi-Fi cells in a macro and micro overlaid network. It can be seen that the number of users getting less than 10Mb/s is significantly reduced from 12% to 5% with only 200 Wi-Fi cells in a 1 km^2 area. An alternative would be to deploy more indoor Wi-Fi cells and fewer outdoor cells as shown

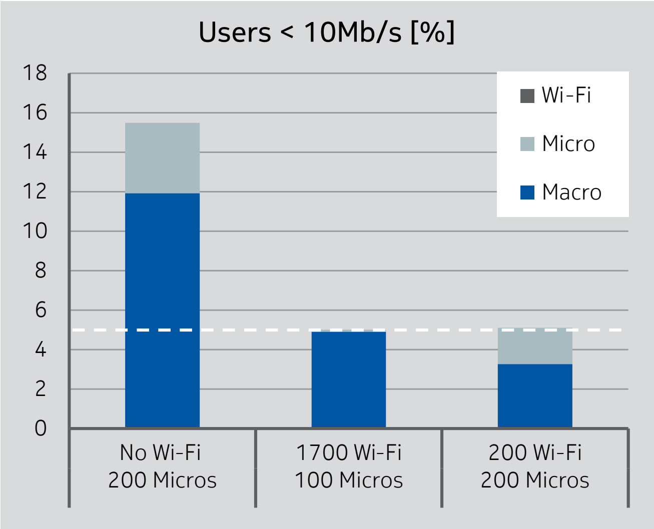


Figure 3: Example of indoor offload via Wi-Fi cells in a dense urban area with 20 macro sites and 200 micro cells.

with an example of 1700 Wi-Fi and 100 micro cells. The split between outdoor and indoor cells depends on which one is the most cost efficient solution.

The deployment of indoor small cells faces the same challenges as outdoor small cell deployments, apart from the interference management benefits for natural shielding provided by the structure of the buildings. However, interference management is still required between the indoor cells and between indoor cells and the outdoor network. In-band deployment is the default option due to operators having limited spectrum resources.

4.2.2. Indoor coverage and capacity with pico cluster

Many indoor public or enterprise areas are evolving into hot zones or are strategically important areas to serve for operators, and a new approach that combines the benefits and simplicity of Wi-Fi with the robustness and guaranteed Quality of Experience (QoE) of 3GPP pico cells will be required. Our studies have shown that, where allowed, high power indoor small cells of 30 dBm can reduce the number of cells needed by up to 50% compared to small cells of 20 dBm.

Nokia's indoor solutions take into account the future need for very high cell density with a pico cluster approach. This provides a solution that can use the installed Ethernet network as backhaul (slashing the cost of deploying dedicated cabling infrastructure and providing for faster deployments), with aggregation of connected APs and local breakout to limit network impact and provide local routing to enterprise Local Areas Network (LAN) servers if required. For more economical deployments, Self-Optimizing Networks (SON) principles are used to simplify operations and maintenance, in addition to innovative interference management techniques that ensure scalability (low impact/fast deployment of new pico).

To complement an older DAS system using indoor small cells adding LTE capacity as an overlay, we have done a study in a 60 floor high rise with different indoor deployment options.

Figure 4 shows an example of the capacity of different indoor solutions in a 60 floor high rise building, with each scenario providing 95% coverage. The first case uses DAS for indoor coverage and the second uses the DAS infrastructure with a small cell on every floor doubling the capacity. Deploying further small cells improves capacity significantly. The final case shows a combination of DAS in the common area and small cells in the dedicated office areas. The indoor deployment with distributed small cells provides significantly more capacity, with the same coverage as DAS, for a reduced cost.

Scenario	# of eNB/small cells per floor	# of Antennas	Capacity per Floor
20W eNB connected to **DAS**	1 per 2 floors	21	**56 Mbps**
5W small cell connected to **DAS**	1	21	**112 Mbps**
5W small cell with **built-in antenna**	8	8	**543 Mbps**
0.25W small cell with **built-in antenna**	18	18	**1335 Mbps**
5W small cell connected to **DAS** in **COMMON-AREAS-ONLY and 0.25W** in other areas.	1 five-W and 5 quarter-W	19 (14 DAS + 5 Built In)	**489 Mbps**

Figure 4: Capacity of different indoor solutions in 60 floor high rise building.

4.2.3. Ultra dense indoor deployment

Increasing the traffic density in deployment areas like airports, campuses, bus stations and large shopping malls requires a combination of outdoor and indoor deployment to provide seamless coverage and capacity. Such an example is shown in Figure 5 where indoor LTE small cell and WLAN/ 802.11n/ac solutions complement outdoor macro and small cell deployment. The ratio of users getting more than 10 Mbit/s is increased from 80% to 90% by deploying an indoor cell for every ~500m^2.

In enterprise deployment environments, where the locations and transmit power levels of the indoor small cells (Wi-Fi or pico) can be optimized, the number of indoor small cells required can be significantly reduced, thus providing cost reductions of up to 45% compared to the costs of un-planned residential-like deployment solutions.

In public deployment environments, such as large multi-floor shopping malls, a deployment density of one indoor pico cell per 1000 m^2 floor area is sufficient in order to provide the minimum downlink user data rate of 10 Mbit/s in a 2020 traffic growth scenario as shown in Figure 6.

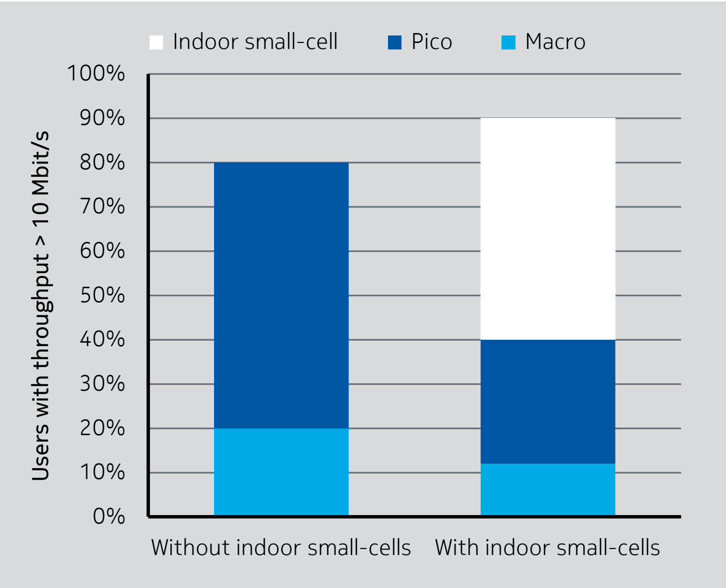


Figure 5: Example of outdoor and indoor small cell (4G/LTE and Wi-Fi 802.11n/ac) coverage probability performance under a typical dense urban deployment scenario as expected in 2020.

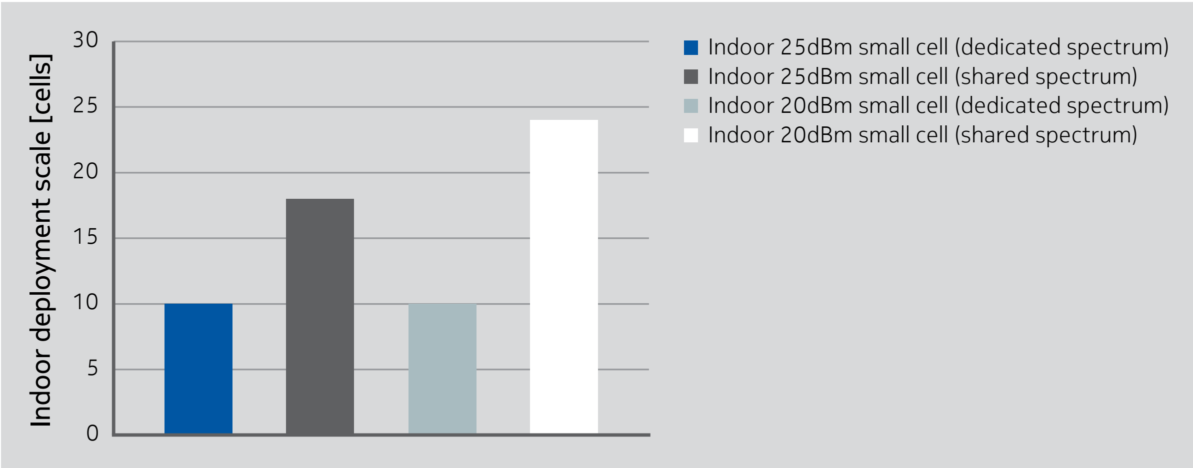


Figure 6: Example of dense indoor deployment per 10,000 m² with expected 2020 traffic levels.

Figure 6 shows an ultra-dense indoor deployment with different transmit power and spectrum allocation. It can be seen that sharing spectrum with outdoor macro and small cells will significantly increase the number of required indoor small cells.

4.2.4. Feature parity

Software and feature parity between macro and micro/pico cells is one of the critical steps needed in small cell deployment, both outdoor and indoor. It will help create tighter integration between the two network layers, which leads to improved HetNet performance and thus also better coverage and a consistent user experience.

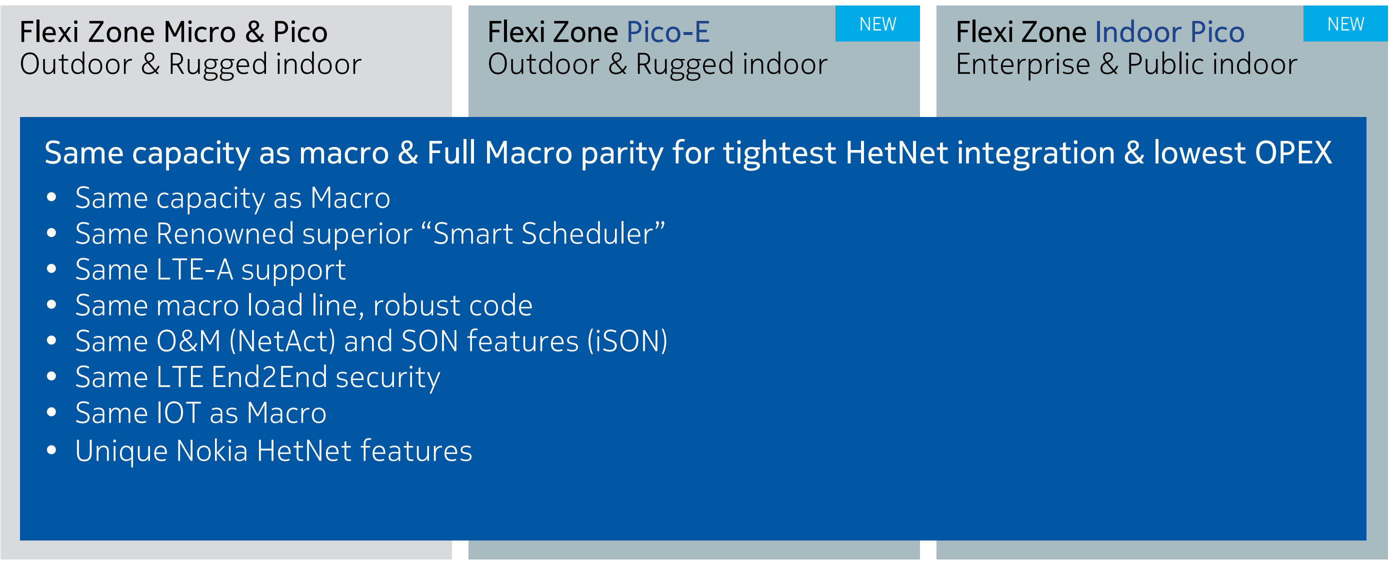


Figure 7 shows the Nokia feature parity between small cells and macro cells that tight integration with macro cells allows, enabling key features like carrier aggregation and other features described in the outdoor deployment section. Furthermore, feature parity significantly simplifies deployment, operation and maintenance of small cells.

5. Cost considerations

Total Cost of Ownership (TCO) is one of the most important deciding factors when choosing a network deployment path. The section analyzes an example of indoor deployment with identical coverage for each deployment case.

5.1. Indoor small cell business case

For large indoor high capacity areas such as airports, shopping malls and high rise buildings, it was shown in the previous section that indoor small cells provide significantly better capacity with similar coverage to a DAS.

Nokia has further done a study to compare the cost of indoor small cells compared with DAS in a large high rise building with mixed residential, shopping, entertainment and leisure areas. The study again provides the same coverage for all analyzed scenarios to enable a full comparison.

Figure 8 shows both the capacity and the TCO of the Nokia indoor Flexi Zone compared with passive DAS, active DAS and CAT based DAS. The indoor small cells provide more than 30% lower TCO compared to the cheapest DAS solution, with a very large capacity gain compared to any of the DAS solutions. The cost of the radio equipment is higher for indoor small cells compared to the DAS radio but the deployment, installation and other CAPEX are significantly reduced, creating a very attractive business case for indoor small cells.

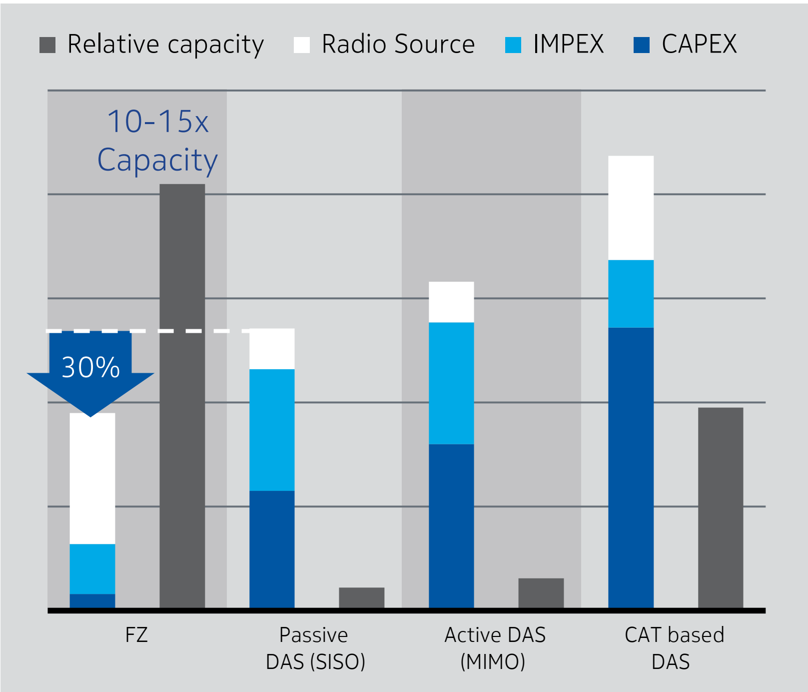


Figure 8: Normalized coverage TCO for a large public indoor building

5.2. Nokia indoor solutions

Nokia supports operators as they wrestle with the increasing complexities of their evolving networks. We provide smart and unified heterogeneous networks together with our award winning Flexi Zone solution, Flexi Lite & Smart Wi-Fi. Nokia provides both product and services designed to enable operators to provide the best mobile broadband user experience.

In other words, Nokia provides solutions for both coverage and capacity. This is a unified approach, with services that deliver optimized HetNet solutions with feature parity for all use cases, enabling operators to serve the growing demand for mobile data
while keeping costs firmly under control.

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